

# Intra-Articular Risks of Suprapatellar Nailing

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## Abstract

To determine the risks to local anatomy near the starting point for tibial nailing during suprapatellar nailing, 15 fresh-frozen hemipelvis specimens were nailed using a suprapatellar technique. After nail passage, the menisci and articular surfaces, anterior cruciate ligament (ACL) insertion, intermeniscal ligament, and fat pad were assessed for injury. The distance from the entry portal to the menisci, articular surfaces, and ACL insertion was determined.

Medial meniscus injury occurred in 1 (6.7%) specimen and medial articular injury in 2 (13%). Nails passed through the fat pad in all specimens; intermeniscal ligament injury occurred in 3 (20%) specimens. The ACL insertion and lateral structures were not injured in any specimen. The distance from the entry portal margin to the lateral and medial menisci was  $6.46 \pm 2.47$  mm and  $4.74 \pm 3.17$  mm, respectively. The distances to the lateral and medial articular margins measured  $10.33 \pm 3.62$  mm and  $6.54 \pm 3.57$  mm, respectively. The distance to the ACL insertion averaged  $5.80 \pm 3.94$  mm.

Suprapatellar nailing is associated with a risk of injury to anterior knee structures comparable to other nailing techniques. Additional clinical studies are warranted to further define the role of this technique in the management of tibial fractures.

Intramedullary nailing is the preferred operative technique for management of most tibia fractures.<sup>1-5</sup> Techniques for obtaining a start point on the proximal tibia for nailing have involved lateral or medial parapatellar arthrotomies or a patellar tendon splitting

approach.<sup>5-7</sup> To obtain the necessary nail trajectory, knee flexion is required, making biplanar imaging and placement of adjuvant clamps or other reduction aids difficult.<sup>8,9</sup> Deforming forces encountered during this positioning have led to malalignment in nailing specific fracture patterns (ie, proximal fractures) in up to 84% of cases.<sup>10,11</sup> As a result, alternative nailing techniques have recently been described which utilize a semi-extended limb position and either a quadriceps split or superomedial patellar incision with lateral patellar mobilization in order to use the trochlear groove as a conduit for nail passage (ie, suprapatellar nailing).<sup>8,9,12,13</sup> With instrumentation now widely available, this technique has grown in popularity for management of both proximal third fractures as well as other tibia fractures.<sup>14,15</sup> We hypothesized that the use of suprapatellar tibial nail insertion using standard radiographic landmarks would place the entry portal within the anatomic safe zone, with minimal risk to anterior knee structures.

## MATERIAL AND METHODS

Fifteen fresh frozen cadaveric hemipelvis specimens were obtained and used for this study (LifeLegacy Foundation, Phoenix, Arizona). Specimens were positioned on a radiolucent table with the knees in 10° to 20° of flexion using a rolled bump (Figure 1). All specimens underwent suprapatellar nailing by the surgical team, consisting of an experienced fellowship-trained orthopedic traumatologist and senior resident. Standard instrumentation manufactured for the suprapatellar technique (Smith & Nephew, Memphis, Tennessee) was utilized. A medial

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**Figure 1.** Operative setup, with cadaveric limb positioned in approximately 10° to 20° of flexion over a rolled bump.

parapatellar arthrotomy of the superior two-thirds of the retinaculum and extending slightly into the quadriceps tendon was utilized to access the knee joint.<sup>16</sup> The patella was subluxed laterally and a large-caliber trocar and cannula placed bluntly across the patellofemoral joint to gain access to the proximal tibial surface. A 3.2 mm guidewire was inserted into the proximal tibia within the radiographic safe zone, just medial to the lateral tibial spine on a perfect anteroposterior projection and immediately adjacent and anterior to the articular surface on the lateral projection, as recommended by McConnell and colleagues<sup>17</sup> (Figure 2). The proximal tibia was



**Figure 2.** AP and lateral fluoroscopic images depicting the radiographic starting point used in all specimens. This point is just medial to the lateral tibial spine on the AP and immediately anterior to the articular surface on the lateral projection.

prepared using the 12.5 mm entry reamer and a ball tip guidewire passed into the intramedullary canal. The canal was reamed to a diameter of 11 mm and a 10-mm-cannulated tibial nail (Trigen Meta-Nail, Smith and Nephew, Memphis, Tennessee) was inserted and seated into the intramedullary canal.

After each procedure, the cadaveric knees were dissected by transecting the quadriceps tendon and reflecting it distally. Each knee was inspected and photographed by 2 independent investigators. The fat pad, intermeniscal ligament, anterior cruciate ligament, and menisci were assessed for injury; total meniscectomies were then performed to assess the medial and lateral articular surfaces. A small metric ruler was placed and a calibrated digital photograph of the exposed tibial plateau was taken perpendicular to the joint surface before and after meniscectomy. These photographs were analyzed using a computer software program, ImageJ (National Institutes of Health, Bethesda, Maryland), which compares a known distance (eg, the metric ruler in each image) to the actual number of pixels in the digital photograph. The software uses this information to calculate linear distances.

Demographic data for each cadaveric specimen was collected and included age, gender, height, weight, and previous medical and surgical history. The anterior cruciate ligament (ACL) insertion, medial and lateral menisci, and medial and lateral tibial articular surfaces were assessed and recorded as no injury, abutment, or violation, according to a previously published protocol.<sup>18</sup> The intermeniscal ligament was also assessed in an identical manner; the retropatellar fat pad was assessed as either intact or violated. ImageJ (Bethesda, MD) computer software was used to determine the following linear distances: distance from the margin of the entry portal to the medial and lateral menisci and articular surfaces, and distance to the ACL insertion. Due to limitations of a cadaveric study model with regard to tissue pliability,

injury to the patellofemoral joint was not a primary end point of the study.

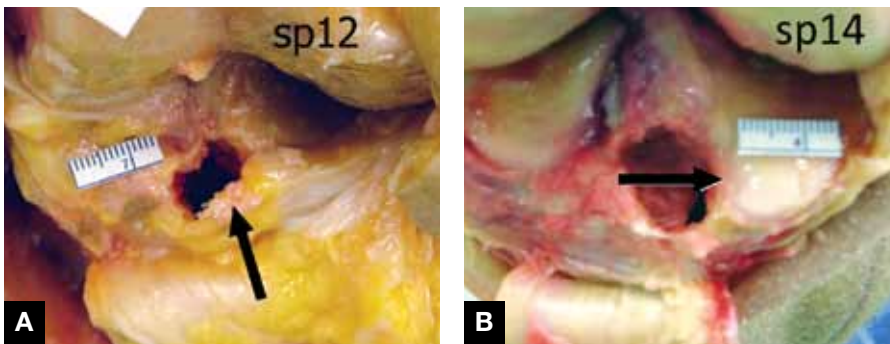
## RESULTS

Among 15 patients, the medial meniscus was violated in 1 (6.7%) specimen and abutted in another 1 (6.7%), while the medial articular margin was violated in 2 (13%) specimens (Figures 3A, 3B). In all 3 of the specimens with medial side injury, only the peripheral 1 to 2 mm was involved, without evidence of major injury to either the meniscus or articular surface. Nails passed through the retropatellar fat pad in all specimens; the intermeniscal ligament was violated in 3 (20%) specimens and abutted in another 1 (6.7%). On the lateral side, no meniscal or articular surface violations occurred, with 2 (13%) menisci abutted. The ACL insertion was abutted in 6 (40%) specimens with no violations identified. Abrasions to the trochlea were noted in 7 (47%) specimens.

The average distances from the entry portal margin to the lateral and medial menisci were  $6.46 \pm 2.47$  mm and  $4.74 \pm 3.17$  mm, respectively. The average distances to the lateral and medial articular margins measured  $10.33 \pm 3.62$  mm and  $6.54 \pm 3.57$  mm, respectively. The distance to the ACL insertion averaged  $5.80 \pm 3.94$  mm.

## DISCUSSION

The results of this cadaver study suggest that tibial nailing using a superomedial arthrotomy and lateral patellar mobilization in the semi-extended position presents similar risk to anterior knee structures when compared to standard tibial nailing techniques and a recently described suprapatellar technique using a quadriceps splitting approach.<sup>13,18,19</sup> All violations of the anatomy adjacent to the starting point for tibial nailing were seen on the medial side of the knee, where medial meniscus injury occurred in 6.7% of specimens and medial articular surface injury in 13% of specimens. We propose that difficulties with patellar mobilization when using the medially-based supra



**Figures 3.** Photographs depicting injury to the medial meniscus (A), and injury to the medial articular surface (B) in separate cadaveric specimens.

patellar approach may force both the entry reamer and nail to enter the tibia from a more medial trajectory, despite using an appropriate starting point. Because clinical situations can be encountered in which patellar mobilization proves difficult (ie, previous medial patellofemoral ligament reconstruction or other procedures on the medial aspect of the knee which may be complicated by scarring and/or adhesions, arthrosis involving the patellofemoral joint), it may be reasonable in these instances to move the starting point laterally by a few millimeters to counteract these medializing forces if using a superomedial arthrotomy.

The clinical relevance of injury to the medial meniscus or medial articular surface remains poorly defined, with the most pressing concern whether injury is associated with the increased incidence of anterior knee pain seen after tibial nailing. It is difficult to predict whether the 2 minor meniscal injuries reported in our study, both of which consisted of 1 to 2 mm of marginal fraying without tears, would be associated with knee pain. Major meniscus injuries would seem more likely to represent a source of pain or mechanical symptoms and these were not encountered in this study. We also expect that violation of 1 to 2 mm to the medial articular margin adjacent to the ideal starting point would not represent a significant pain generator, as this area lies in a submeniscal zone, where subchondral loads have been shown to be significantly decreased.<sup>20,21</sup>

Eastman and colleagues<sup>13</sup> have recently performed a cadaveric study with similar methods to those employed in the current study. The major difference between the 2 studies involves the location of the arthrotomy: they utilized a 2 cm midline quadriceps split to gain access to the knee joint, while we utilized a superomedial arthrotomy as described by Tornetta and Collins<sup>8</sup> and recommended with the instrumentation developed for this technique.<sup>8,9,13,16</sup> When compared to the findings of Eastman and colleagues,<sup>13</sup> our results are similar with regard to injury to the articular surfaces, menisci, and ACL footprint. Our results do suggest, however, that the use of a superomedial arthrotomy leaves the entry portal slightly more medial when compared to splitting the quadriceps in the midline (4.74 mm to medial meniscus vs 6.6 mm).<sup>13</sup> Use of a superomedial

arthrotomy, which is off axis from the tibia, requires the patella to be more lateralized in order to place the trocar and cannula, and likely forces the reamer and nail to enter from a more medial trajectory despite obtaining the correct starting point. The safe zone for insertion of intramedullary nails on the proximal aspect of the tibia has been well described by both Hernigou and Cohen,<sup>19</sup> and Tornetta and colleagues.<sup>18</sup> Both were cadaveric studies utilizing a

10 mm entry awl; the former inserted a 10 mm nail while the latter inserted an 11 mm nail. Neither of these studies' methodology represent the most modern nailing techniques, in which proximal metaphyseal opening is performed to at least half a millimeter greater than the proximal diameter of the nail to allow safe nail passage. Current tibial nails from a variety of manufacturers come with proximal diameters of 11 to 12 mm for a 10 mm diameter nail.<sup>22-24</sup> In contrast to these 2 studies, we utilized a 12.5 mm entry reamer to place a standard 10 mm diameter nail with a proximal diameter of 12 mm. By performing the procedures identical to modern clinical practice we created an entry portal larger than either of the previous two cadaveric studies. We can theorize that had we used a smaller entry portal and placed a nail with a 10 mm proximal diameter, our incidence of intra-articular injury may in fact have been lower. Hernigou and Cohen<sup>19</sup> estimated that the use of a larger 12 mm entry portal would likely have led to medial meniscus injury in nearly 40% of their cases.

In all specimens the retropatellar fat pad was violated. This was an expected outcome given the location of the fat pad and use of an intra-articular nail trajectory toward the safe zone. Although the retropatellar fat pad has been associated with inflammation and pain in chronic conditions (Hoffa pad disease), there is no evidence that acute injury is associated with postoperative knee pain, and the use of cannulas should prevent the accumulation of debris both within the fat pad and in the knee joint, particularly if the cannula position is not changed and the reamings are removed from inside the cannula after each sequential reaming. Previous arthroscopic literature has identified fat pad injury as one potential source of postoperative stiffness and pain.<sup>25</sup> In contrast, knee arthroplasty literature has demonstrated that complete fat pad excision is not associated with an increase in either knee pain or patellar tendon shortening.<sup>26</sup>

Intermeniscal ligament injury was found in 20% of specimens, which is similar to the finding of Hernigou and Cohen, who identified intermeniscal ligament injuries in 28.6% and 14% of medial paratendinous and transtendinous approaches, respectively.<sup>19</sup> While some argue that it represents a vestigial structure,<sup>27</sup> others report it as the pri-

mary insertion for the anterior horn of the medial meniscus in 24% of knees, with injury potentially associated with meniscal instability and pain.<sup>28</sup> While Tornetta and colleagues<sup>18</sup> did not report injuries to this structure, Eastman and colleagues<sup>13</sup> reported a much higher incidence in their study, with 81.2% of intermeniscal ligaments injured 1 to 2 mm.<sup>13</sup> It is not completely clear to the authors why Eastman and colleagues<sup>13</sup> had such a high incidence of injury when compared to our findings and those of Hernigou and Cohen.<sup>19</sup> It may be that the insertion vector from a midline suprapatellar approach, because of the position of the patella, forces the starting point more posterior toward the margin of the articular surface and thus directly adjacent to the intermeniscal ligament. Despite concerns for intermeniscal ligament injury, it is known that a superior and posterior starting point is biomechanically important in decreasing posterior hoop stresses during nailing,<sup>29</sup> and has previously been recommended for proximal third tibia fractures by multiple authors.<sup>30,31</sup>

The clinical utility of our results remain unknown. Currently multiple theories for anterior knee pain after intramedullary nailing have been put forth, with no single culprit for causing pain identified.<sup>7,18,19,32-34</sup> It seems intuitive that injury to intra-articular structures can be a causative factor in knee pain and their injury should be limited by correct use of intraoperative fluoroscopy and sound surgical technique. Nonetheless, the currently described approaches, including suprapatellar nailing, all carry some intra-articular risk. This risk can potentially be mitigated in suprapatellar nailing by extending the arthrotomy to gain easier direct visualization of the joint, or during parapatellar or tendon-splitting approaches by making a formal arthrotomy and sweeping away the fat pad.

This study has multiple scientific limitations, which warrant review. First, surgery was performed on only 15 specimens in a noncomparative study. Second, this was a cadaveric study, which relied mostly on the limbs of elderly individuals where knees are commonly affected by arthritic changes, making limbs stiffer than their cadaveric nature alone would imply. In addition, the cadaveric nature of the limbs also made them less pliable in general. For these reasons, data regarding injury to the patellofemoral joint, while clinically relevant, is of limited utility in this study, in our opinion. Although 47% of the cadaveric specimens had abrasions noted on the trochlear cartilage, this finding was not noted in another recent cadaveric study on suprapatellar nailing using a quadriceps splitting approach, which found a similar injury profile to the menisci and articular surface.<sup>13</sup> In clinical practice, where tissue pliability is not a concern as in cadavers, and particularly in a patient population devoid of arthritic changes, frank injury to the patellofemoral joint (ie, scuffing, abrasions as seen in this study) would not be expected to occur. The major risk to the patellofemoral joint in clinical practice is chondrolysis from prolonged pressure against the articular surface

by the cannula, especially in patients where the cannula has a tight fit in the joint. Future clinical studies using delayed arthroscopy or magnetic resonance imaging are necessary to answer that critical question.

Another limitation involves the nature of our data collection in determining linear distances to the menisci, ACL footprint, and articular surfaces. Compared to previous cadaveric studies on the subject which utilized calipers for measurement, we utilized high resolution digital photography with specialized software to calculate linear distances. This technique's major limitation is its 2-dimensionality. We reduced this as much as possible by taking our photographs perpendicular to the tibial plateau. The major benefits of using digital photography are its ease and speed of use, combined with the ability to perform multiple independent measurements with accuracy increasing as digital image quality increases, because distances are calibrated off the number of pixels in the image. Subjective assessment of injury to structures in this study was done in real time, however, and not based off the images taken.

## CONCLUSION

Based on this cadaveric study, tibial nailing in the semi-extended position with a superomedial arthrotomy and lateral patellar mobilization (ie, suprapatellar nailing) is associated with risks to anterior knee anatomy at the starting point comparable to other previously described tibial nailing techniques. A superomedial arthrotomy places the portal closer to the medial meniscus, compared with a quadriceps splitting approach. We feel that the technique may offer significant advantages in the management of proximal tibia fractures undergoing nailing; however, because risks to the patellofemoral joint have not been clearly elucidated by this or other studies, it may not be the approach of choice for more simple fractures not predisposed to malalignment. Additional clinical studies are warranted to further define the role of this technique in the management of tibia fractures, including those of the proximal third.

## AUTHORS' DISCLOSURE STATEMENT

The authors report no actual or potential conflict of interest related to this article. The views and opinions described herein are those of the authors alone, and should not be construed as reflecting those of the Department of the Army, Department of Defense, or the United States Government.

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